Group # 14
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Motion Capture Lite

UNIVERSITY OF WATERLOO

Motivation

Motion Capture is a widely used digital tracking technique valued at $180M in 2022, expected to reach $600M by 2030 [1]. Primarily used in entertainment, sports, and robotics, existing solutions are expensive, involve elaborate setups, and have human-centered tracking.

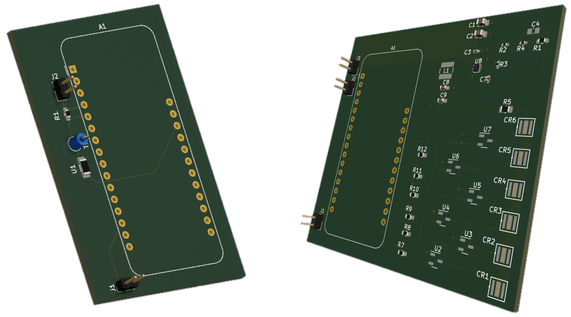
Objective

This project aims to create a cost-effective "lite" motion-capture device that can track small objects using tags (containing a phototransistor) and beamers (consisting of IR LEDs).

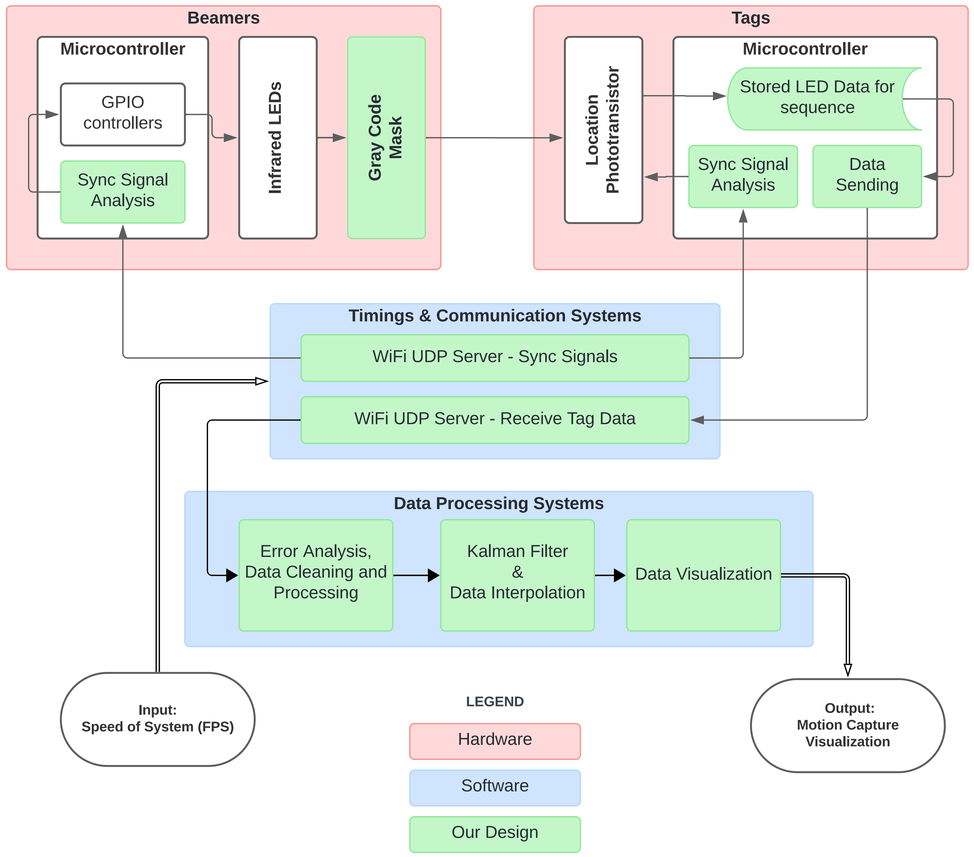
Advantages

- **Low Cost:** Our systems mainly consist of photosensors, LEDs and cheap microcontrollers
- **Wireless:** Tracking tags are wireless and easy to move-around
- **Quick Setup:** Setup system within 10s
- **Real-Time:** Instant motion tracking via visualization software

Tag & Beamer PCB Design



System Design



Theory

Gray Code Masking: The beamers flash each of the 4 LEDs successively, and the gray code mask placed on the beamer helps the tag identify the region of the beamer.

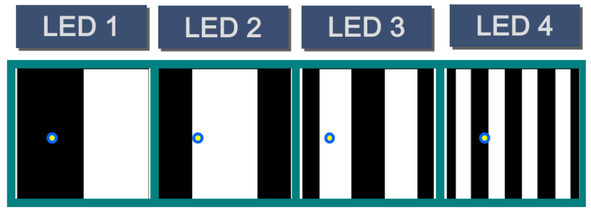


Image Source: [2]

WiFi Communication: A central server sends a SYNC signal to the beamers and tags to start flashing LEDs and reading from the phototransistor respectively.
Data Visualization: Data is validated and passed through a *Kalman Filter*. The data is further interpolated before being visualized using *Python Matplotlib*.

Design Iterations / Alternatives

- **Wired Communication:** A custom serial-based communication protocol was considered, but eventually rejected due to limitations on range of motion and portability.
- **Breadbroad to PCB**: We moved our designs to PCBs to reduce the footprint and to allow the use of more powerful LEDs.
- **TCP / UDP:** To avoid the additional round-trip required due to an acknowledgment and to increase the speed of the system, we chose UDP instead of TCP for our WiFi communication protocol.
- **Batching Data**: Instead of transmitting a single result for each beamer sequence, we batched 16 results together to minimize network traffic.
- **Visualization:** Many choices for data visualization were considered, including *Rust EGUI* and *React - Python Matplotlib* was chosen due to compatibility with existing server code and *Kalman Filter* functions.

Results

Through our motion capture system, we were able to achieve motion tracking across **256 regions** in the 2D Plane, and about 4 regions along the Z Axis, at a speed of **2.5 - 5 FPS.**

Acknowledgments

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References:
[1] Z. M. Research, "Global 3D Motion Capture System Market Size: Revenue Valued at USD 180 Million in 2022, Expected to Reach USD 600 Million by 2030 at a CAGR of 14.12%," GlobeNewswire News Room, Apr. 04, 2023. [Accessed Jun. 29, 2023]
[2] R. Raskar et al., "Prakash: Lighting Aware Motion Capture using Photosensing Markers and Multiplexed Illuminators" [Online]. Available: https://web.media.mit.edu/~raskar/LumiNetra/Paper/CONFIDENTIALraskarSig07OpticalMocapPaper.pdf. [Accessed: Jun. 29, 2023]

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